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# Changes in testicular morphology and oxidative stress biomarkers in 60-day-old Sprague Dawley rats following exposure to continuous 900-MHz electromagnetic field for 1 h a day throughout adolescence

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## Highlights

- We examined the effect of electromagnetic field on adolescent rat testicle.
- Exposure to 900-MHz EMF adversely affects adolescent rat testicle morphology.
- Exposure to 900-MHz EMF changes adolescent rat testicle oxidative stress biomarkers.

## Abstract

The purpose of this study was to investigate the 60-day-old male rat testis following exposure to continuous 900-megahertz (MHz) electromagnetic field (EMF) throughout the adolescent period using histopathological and biochemical analysis methods. Twenty-four Sprague Dawley rats aged 21 days were randomly and equally (n = 8) divided into three groups. No procedure was performed on the control group rats. The sham group rats were held in an EMF-cage without exposure to EMF. The EMF group rats were exposed to continuous 900-MHz EMF for 1 h each day inside the EMF-cage during adolescence. On postnatal day 60 the testes were extracted and divided into right and left halves. The right half was used for histopathological evaluation and the left half for biochemical analyses. Our results show that changes may occur in morphology and oxidative stress biomarkers in the rat testis following exposure to continuous 900-MHz EMF throughout the adolescent period.

## Introduction

Cell phones are one of the most widely used communication tools today, and have become an essential part of daily life. It is quite possible that the use of cell phones will also increase ever further due to advertising campaigns encouraging them, in addition to the benefits they undoubtedly bestow in day-to-day life. However, this widespread use of cell phones has also led to serious inquiry into the health effects caused by the electromagnetic fields (EMF) which they emit [1]. There are currently approximately 7 billion cell phone subscriptions worldwide [[2], [3], [4]], and the increasing use of these and other EMF-emitting devices and systems is giving rise to a new and growing area of exposure to EMF [5]. In 2011, the World Health Organization International Agency for Research on Cancer included the electromagnetic radiation emitted by cell phones and other such wireless devices in the Group 2B class, possibly carcinogenic to humans. This class also includes pesticides such as dichloro-diphenyl-trichloroethane, gasoline exhaust, burning coal, dry cleaning fluids and jet fuels [6].

In order to receive incoming calls, short message service messages and e-mails, cell phones have to be connected to a specific network. The communication processor therefore operates in an active manner, albeit at a low level, and continues transmitting in standby mode. Energy consumptıon varies in association with the background applications that are still operating in standby mode. Standby mode is a preparatory period for when the mobile phone will be used in an active manner. Phones must be kept in standby mode for the time when they will be used actively (for test message communication, for instance). The energy used in standby mode must therefore not be overlooked [7,8]. In other words, the EMF

emitted by a cell phone in standby mode also affects tissues in the area where it is carried. For example, if it is always carried in a trouser pocket, it may affect the testes in males or the ovaria in women, or if it is carried in a chest pocket, it may affect breast tissue in women. Widespread use of cell phones in childhood and adolescence in particular has further exacerbated existing concerns. Children and adolescents, whose tissues and organs have not yet reached adult status, will probably be more affected by EMF [9,10]. Although the number of studies reporting pernicious effects on human and animal tissues of the EMF emitted by cell phones is growing on a continuous basis [3,[11], [12], [13], [14], [15], [16]], the attractive and widespread advertising campaigns organized by cell phone companies are reinforcing the idea that their use is entirely harmless. For example, Tarulli et al. [17] reported that problems in spermatogenesis may occur as a result of compromise of Sertoli cell maturation and differentiation in young males, and that infertility may result in men.

There is a specific equilibrium between the rate of formation of free radicals and their intra- and extracellular elimination. If this oxidative balance is compromised in favor of oxidative systems, this leads to the state known as oxidative stress [18]. Lipid peroxidation (LPO) and reactive oxygen products occur as a result of oxidative stress, thus leading to biomolecular injury. Some studies have reported that the EMF emitted by cell phones causes an increase in free radicals and thus affects antioxidant [19,20]. Oxidative damage in cellular structures, membranes and molecules under the effect of EMF may be explained in terms of the sensitivity of biological membranes, which are particularly rich in unsaturated fatty acids, to free radical attack. Malondialdehyde (MDA) is a product of the breakdown of unsaturated fatty acids and an important marker of lipid oxidation in tissue [21]. Antioxidants belonging to the organism's antioxidant system, such as catalase (CAT), glutathione (GSH) and superoxide dismutase (SOD) also protect cells against lipid oxidation [22,23].

Various factors of exogenous and endogenous origins may be involved in a change in the course of apoptosis or programmed cell death, a normal component of the development of multicellular organisms. Reactive oxygen species (ROS) deriving from EMF have been identified as one such factor inducing this process that causes cellular damage [24]. Studies have reported increases in the incidence of germ cell death and the apoptotic index (AI) in spermatogenic cells as a result of exposure to EMF [25,26]. Studies by Khaki et al. [27,28] reported that EMF can lead to structural or functional changes such as spermatogenesis in organs and tissues related to the reproductive system.

Electromagnetic waves are a wave motion formed by electric and magnetic fields, and the distribution product formed when the electromagnetic field is separated into various frequency components is known as the spectrum. Radiation energy is emitted as waves and

particles in an environment, while electromagnetic radiation is the emission of an electromagnetic wave in any environment. An electromagnetic wave is generally divided into 'ionized electromagnetic radiation' and 'non-ionized electromagnetic radiation' [29]. When the wavelength decreases and electromagnetic radiation encounters matter, it behaves more like an energy mass than a wave. These energy clusters are known as quanta or photons. Electromagnetic radiations of this kind include X and gamma rays. When these rays with increasing energy encounter matter they ionize them, thus impairing their structural, or vital, functions. These rays therefore represent the ionized radiation group, and another electromagnetic radiation group the non-ionized radiation group. These are classified, from lowest energy to the highest, as radio waves, microwaves, infrared radiation, visible rays, laser and ultraviolet rays. The radiation caused by mobile communications systems is an example of non-ionized radiation [[30], [31]]

The most widely used cellular communication systems are Global System for Mobile Communications-900 (GSM-900) and Distributed Control System-1800 (DCS-1800) [3]. While GSM-900 operates at a frequency band of 880–960 MHz (MHz), DCS-1800 uses a frequency band of 1710–1880 MHz. The only difference between these systems is the frequency bands they employ. The GSM-900 system is widely used in Turkey and Europe. Adolescence in rodents is divided into three stages; early adolescence (pre-adolescent animals, postnatal days 21–34), middle adolescence (periadolescent, postnatal days 34–46) and late adolescence (young adult, postnatal days 46–59) [32]. For all these reasons, the purpose of our study was to investigate changes in testis morphology and oxidative stress markers in rats exposed to a continuous 900-MHz EMF for 1 h a day throughout adolescence, also considering the stages of adolescence in rodents.

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## Section snippets

### Groups and study design

All procedures were designed to be compatible with the Guidelines for the Care and Use of Laboratory Animals published by the U.S. National Institutes of Health. Written authorization is a legal requirement for any animal experiment in Turkey. All surgical and

other experimental procedures to be performed were therefore reviewed by the members of the Karadeniz Technical University (KTU) Animal Care and Ethics Committee, and were approved with official, written authorization. All analyses, …

## Testis weight findings

No statistically significant difference was observed in testis tissue weights between Gr-CNT and Gr-SHM, but a significant decrease in testicular weight occurred in Gr-EMF compared to Gr-CNT and Gr-SHM ($p < 0.05$) (Table 1). …

## Histopathological analysis results

Normal histological seminiferous tubule architecture and interstitial connective tissue between seminiferous tubules containing masses of Leydig cells with acidophilic cytoplasm with a vesicular nucleus were observed in Gr-CNT sections stained with H&E. The seminiferous …

## Discussion

The testis weight results from this study are compatible with those from previous research. For example, a previous study by Odacı et al. [48] reported that 900-MHz EMF applied during the prenatal period led to a significant decrease in testis weight on postnatal day 60. In the present study, too, a decrease in testis weight was observed in Gr-EMF compared to both Gr-CNT and Gr-SHM. On the basis of these findings, it may be suggested that exposure to EMF in both the pre- and post-natal periods …

## Disclosure statement

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper. …

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## Conflict of interest

There is no conflict of interest including any financial, personal or other relationships with other people or organizations that could inappropriately influence, or be perceived to influence this work. …

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### Biochemical, immunohistochemical and morphometrical investigation of the effect of thymoquinone on the rat testis following exposure to a 900-MHz electromagnetic field

2020, Acta Histochemica

> *Citation Excerpt :*
>
> …Overproduction of ROS can result in oxidative damages to protein, lipid and DNA in single nucleated cells of human peripheral blood (Lu et al., 2012). EMF radiation also can induce change in genomes, spatial memory, male and female reproductive systems, kidney and hippocampal pyramidal cells (McCann et al., 1998; Guney et al., 2007; Bas et al., 2009; Hancı et al., 2018; Ulubay et al., 2015; Tang et al., 2015). Detrimental effects of EMF exposure have been observed in embryo organogenesis and brain cell development as well as the reproductive potential of female rat pups (Sonmez et al., 2010; Tenorio et al., 2011)….

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## The protective role of spermine against male reproductive aberrations induced by exposure to electromagnetic field – An experimental investigation in the rat

2019, Toxicology and Applied Pharmacology

> *Citation Excerpt :*
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> …This notion could be justified by the expected accumulation of H2O2 as a consequence of the reduced GPx and catalase activities, and is corroborated by the reported increase in caspase-3 activity in H2O2-treated testicular germ cells (Maheshwari et al., 2009). Instigation of germinal epithelial apoptosis in rats exposed to 900 MHz EMF has been lately reported (Hancı et al., 2018). Our findings revealed notable anti-apoptotic effects of spermine, obviously due to its potent antioxidant capacity, verified by the significant lowering in EMF-induced enhancement in testicular caspase-3 expression.…

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## The protective effect of melatonin on radiofrequency electromagnetic fields of mobile phone-induced testicular damage in an experimental mouse model ↗

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